

CLAIMS

What is claimed is:

1. A ferritic stainless steel comprising:

greater than 25 weight percent chromium;

0.75 to less than 1.5 weight percent molybdenum;

up to 0.05 weight percent carbon; and

at least one of niobium, titanium, and tantalum, wherein the sum of the weight percentages of niobium, titanium, and tantalum satisfies the equation

$$0.4 \leq (\%Nb + \%Ti + \frac{1}{2}(\%Ta)) \leq 1,$$

wherein the coefficient of thermal expansion of the steel is within about 25% of the coefficient of thermal expansion of stabilized zirconia between 20°C (68°F) and 1000°C (1832°F), and wherein the steel exhibits at least one creep property selected from creep rupture strength of at least 1000 psi at 900°C (1652°F), time to 1% creep strain of at least 100 hours at 900°C (1652°F) under load of 1000 psi, and time to 2% creep strain of at least 200 hours at 900°C (1652°F) under load of 1000 psi.

2. The ferritic stainless steel of claim 1, wherein the coefficient of thermal expansion of the steel is at least as great as the coefficient of thermal expansion of stabilized zirconia between 20°C (68°F) and 1000°C (1832°F).

3. The ferritic stainless steel of claim 1, wherein the coefficient of thermal expansion of the steel is within about 25 percent of the coefficient of thermal expansion of yttria-stabilized zirconia between 20°C (68°F) and 1000°C (1832°F).

4. The ferritic stainless steel of claim 1, wherein the steel includes no more than 0.50 weight percent titanium.
5. The ferritic stainless steel of claim 1, wherein the steel includes no more than 0.005 weight percent carbon.
6. The ferritic stainless steel of claim 1, further comprising at least one element selected from the group consisting of up to 0.1 weight percent cerium, up to 0.05 weight percent lanthanum, and up to 0.05 weight percent zirconium.
7. The ferritic stainless steel of claim 1, wherein the steel includes no more than 35 weight percent chromium.
8. The ferritic stainless steel of claim 1, wherein the sum of the weight percentages of niobium, titanium, and tantalum satisfies the equation
$$0.5 \leq (\%Nb + \%Ti + \frac{1}{2}(\%Ta)) \leq 0.75.$$
9. A ferritic stainless steel comprising:
 - 25 up to 35 weight percent chromium;
 - 0.75 to less than 1.5 weight percent molybdenum;
 - up to 0.005 weight percent carbon;

at least one of niobium, titanium, and tantalum, wherein the steel includes no more than 0.50 weight percent titanium, and the sum of the weight percentages of niobium, titanium, and tantalum satisfies the equation

$$0.5 \leq (\%Nb + \%Ti + \frac{1}{2}(\%Ta)) \leq 0.75,$$

wherein the coefficient of thermal expansion of the steel is within about 25 percent of the coefficient of thermal expansion of stabilized zirconia between 20°C (68°F) and 1000°C (1832°F), and wherein the steel exhibits at least one creep property selected from creep rupture strength of at least 1000 psi at 900°C (1652°F), time to 1% creep strain of at least 100 hours at 900°C (1652°F) under load of 1000 psi, and time to 2% creep strain of at least 200 hours at 900°C (1652°F) under load of 1000 psi.

10. The ferritic stainless steel of claim 9, wherein the coefficient of thermal expansion of the steel is at least as great as the coefficient of thermal expansion of stabilized zirconia between 20°C (68°F) and 1000°C (1832°F).

11. The ferritic stainless steel of claim 9, wherein the coefficient of thermal expansion of the steel is at least as great as the coefficient of thermal expansion of yttria-stabilized zirconia between 20°C (68°F) and 1000°C (1832°F).

12. A method for making a ferritic stainless steel, the steel having a coefficient of thermal expansion within about 25 percent of the coefficient of thermal expansion of stabilized zirconia between 20°C (68°F) and 1000°C (1832°F), and at least one creep property selected from creep rupture strength of at least 1000 psi at 900°C (1652°F),

time to 1% creep strain of at least 100 hours at 900°C (1652°F) under load of 1000 psi, and time to 2% creep strain of at least 200 hours at 900°C (1652°F) under load of 1000 psi, the method comprising:

providing a ferritic stainless steel comprising greater than 25 weight percent chromium, 0.75 to less than 1.5 weight percent molybdenum, up to 0.05 weight percent carbon, and at least one of niobium, titanium, and tantalum, wherein the sum of the weight percentages of niobium, titanium, and tantalum satisfies the equation

$$0.4 \leq (\%Nb + \%Ti + \frac{1}{2}(\%Ta)) \leq 1;$$

and

solution annealing the steel.

13. The method of claim 12, further comprising optionally hardening the steel by precipitation heat treating the steel.

14. The method of claim 12, wherein solution annealing the steel comprises heating the steel at a temperature that is at least the greater of the intended service temperature of the steel and 1600°F (871°C).

15. The method of claim 12, wherein the coefficient of thermal expansion of the steel is at least as great as the coefficient of thermal expansion of stabilized zirconia between 20°C (68°F) and 1000°C (1832°F).

16. The method of claim 12, wherein the coefficient of thermal expansion of the steel is within about 25% of the coefficient of thermal expansion of yttria-stabilized zirconia between 20°C (68°F) and 1000°C (1832°F).

17. The method of claim 12, wherein the steel includes no more than 0.50 weight percent titanium.

18. The method of claim 12, wherein the steel includes no more than 0.005 weight percent carbon.

19. The method of claim 12, wherein the steel further comprises at least one element selected from the group consisting of up to 0.1 weight percent cerium, up to 0.05 weight percent lanthanum, and up to 0.05 weight percent zirconium.

20. The method of claim 12, wherein the steel includes no more than 35 weight percent chromium.

21. The method of claim 12, wherein the sum of the weight percentages of niobium, titanium, and tantalum in the steel satisfies the equation

$$0.5 \leq (\%Nb + \%Ti + \frac{1}{2}(\%Ta)) \leq 0.75.$$

22. The method of claim 12, wherein the steel comprises 25 up to 35 weight percent chromium, 0.75 to less than 1.5 weight percent molybdenum, up to 0.005 weight

percent carbon, and at least one of niobium, titanium, and tantalum, wherein the steel includes no more than 0.50 weight percent titanium, and the sum of the weight percentages of niobium, titanium, and tantalum satisfies the equation

$$0.5 \leq (\%Nb + \%Ti + \frac{1}{2}(\%Ta)) \leq 0.75.$$

23. The method of claim 12, further comprising:

processing the steel into a component selected from the group consisting of a component for a solid oxide fuel cell including a stabilized zirconia-containing electrolyte and a component of an oxygen sensor device including stabilized zirconia.

24. The method of claim 23, wherein the component is selected from the group consisting of a separator and an interconnect for a solid oxide fuel cell including a stabilized zirconia-containing electrolyte.

25. An article of manufacture comprising a component including stabilized zirconia adjacent a component including a ferritic stainless steel, the steel comprising:

greater than 25 weight percent chromium;

0.75 to less than 1.5 weight percent molybdenum;

up to 0.05 weight percent carbon; and

at least one of niobium, titanium, and tantalum, wherein the sum of the weight percentages of niobium, titanium, and tantalum satisfies the equation

$$0.4 \leq (\%Nb + \%Ti + \frac{1}{2}(\%Ta)) \leq 1,$$

wherein the steel has a coefficient of thermal expansion within about 25 percent of the coefficient of thermal expansion of the stabilized zirconia between 20°C (68°F) and 1000°C (1832°F), and at least one creep property selected from creep rupture strength of at least 1000 psi at 900°C (1652°F), time to 1% creep strain of at least 100 hours at 900°C (1652°F) under load of 1000 psi, and time to 2% creep strain of at least 200 hours at 900°C (1652°F) under load of 1000 psi.

26. The article of manufacture of claim 25, wherein the coefficient of thermal expansion of the steel is at least as great as the coefficient of thermal expansion of the stabilized zirconia between 20°C (68°F) and 1000°C (1832°F).

27. The article of manufacture of claim 25, wherein the stabilized zirconia is yttria-stabilized zirconia.

28. The article of manufacture of claim 25, wherein the steel includes no more than 0.50 weight percent titanium.

29. The article of manufacture of claim 25, wherein the steel includes no more than 0.005 weight percent carbon.

30. The article of manufacture of claim 25, wherein the steel further comprises at least one element selected from the group consisting of up to 0.1 weight percent cerium, up to 0.05 weight percent lanthanum, and up to 0.05 weight percent zirconium.

31. The article of manufacture of claim 25, wherein the sum of the weight percentages of niobium, titanium, and tantalum in the steel satisfies the equation

$$0.5 \leq (\%Nb + \%Ti + \frac{1}{2}(\%Ta)) \leq 0.75.$$

32. The article of manufacture of claim 25, wherein the steel includes no more than 35 weight percent chromium.

33. The article of manufacture of claim 25, wherein the steel comprises:

25 up to 35 weight percent chromium;

0.75 to less than 1.5 weight percent molybdenum;

up to 0.005 weight percent carbon; and

at least one of niobium, titanium, and tantalum, wherein the steel includes no more than 0.50 weight percent titanium, and the sum of the weight percentages of niobium, titanium, and tantalum satisfies the equation

$$0.5 \leq (\%Nb + \%Ti + \frac{1}{2}(\%Ta)) \leq 0.75.$$

34. The article of manufacture of claim 25, wherein the article of manufacture is a component selected from the group consisting of a component for a solid oxide fuel cell including a stabilized zirconia-containing electrolyte and a component for an oxygen sensor device including stabilized zirconia.

35. The article of manufacture of claim 34, wherein the component is selected from the group consisting of a separator and an interconnect for a solid oxide fuel cell including a stabilized zirconia-containing electrolyte.

36. A solid oxide fuel cell comprising:

an anode;

a cathode;

an electrolyte comprising stabilized zirconia and intermediate the anode and the cathode; and

an interconnect providing a current pathway from the anode, the interconnect comprising a ferritic stainless steel including

greater than 25 weight percent chromium,

0.75 up to 1.5 weight percent molybdenum,

up to 0.05 weight percent carbon, and

at least one of niobium, titanium, and tantalum, wherein the sum of the weight percentages of niobium, titanium, and tantalum satisfies the equation

$$0.4 \leq (\%Nb + \%Ti + \frac{1}{2}\%Ta) \leq 1,$$

wherein the steel has a coefficient of thermal expansion within about 25 percent of the coefficient of thermal expansion of stabilized zirconia between 20°C (68°F) and 1000°C (1832°F) and exhibits at least one creep property selected from creep rupture strength of at least 1000 psi at 900°C (1652°F), time to 1% creep strain of at least 100 hours at 900°C (1652°F) under load of 1000

psi, and time to 2% creep strain of at least 200 hours at 900°C (1652°F) under load of 1000 psi.

37. The solid oxide fuel cell of claim 36, wherein the coefficient of thermal expansion of the steel is at least as great as the coefficient of thermal expansion of stabilized zirconia between 20°C (68°F) and 1000°C (1832°F).

38. The solid oxide fuel cell of claim 36, wherein the coefficient of thermal expansion of the steel is at least as great as the coefficient of thermal expansion of yttria-stabilized zirconia between 20°C (68°F) and 1000°C (1832°F).

39. The solid oxide fuel cell of claim 36, wherein the steel comprises:
25 up to 35 weight percent chromium;
0.75 to less than 1.5 weight percent molybdenum;
up to 0.005 weight percent carbon; and
at least one of niobium, titanium, and tantalum, wherein the steel includes no more than 0.50 weight percent titanium, and the sum of the weight percentages of niobium, titanium, and tantalum satisfies the equation

$$0.5 \leq (\%Nb + \%Ti + \frac{1}{2}(\%Ta)) \leq 0.75.$$